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National Eutrophication Survey, Las Vegas, Nev

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REPORT

ON

SAMMAMISH LAKE

KING COUNTY

WASHINGTON

EPA REGION X

WORKING PAPER NO. 874

WITH THE COOPERATION OF THE

WASHINGTON DEPARTMENT OF ECOLOGY

AND THE

WASHINGTON NATIONAL GUARD

JULY, 1977

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16 ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT ON SAMMAMISH LAKE

KING COUNTY, WASHINGTON

EPA REGION X

by

National Eutrophication Survey

Water and Land Quality Branch
Monitoring Operations Division
Environmental Monitoring & Support Laboratory
Las Vegas, Nevada

and

Special Studies Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

Working Paper No. 874

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY

July 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Washington Department of Ecology for professional involvement, to the Washington National Guard for conducting the tributary sampling phase of the Survey, and to those Washington wastewater treatment plant operators who provided effluent samples and flow data.

Ms. Barbara Blau, Lake Restoration Program, and the staff of the Washington Department of Ecology, Lake Restoration Program, provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper Series.

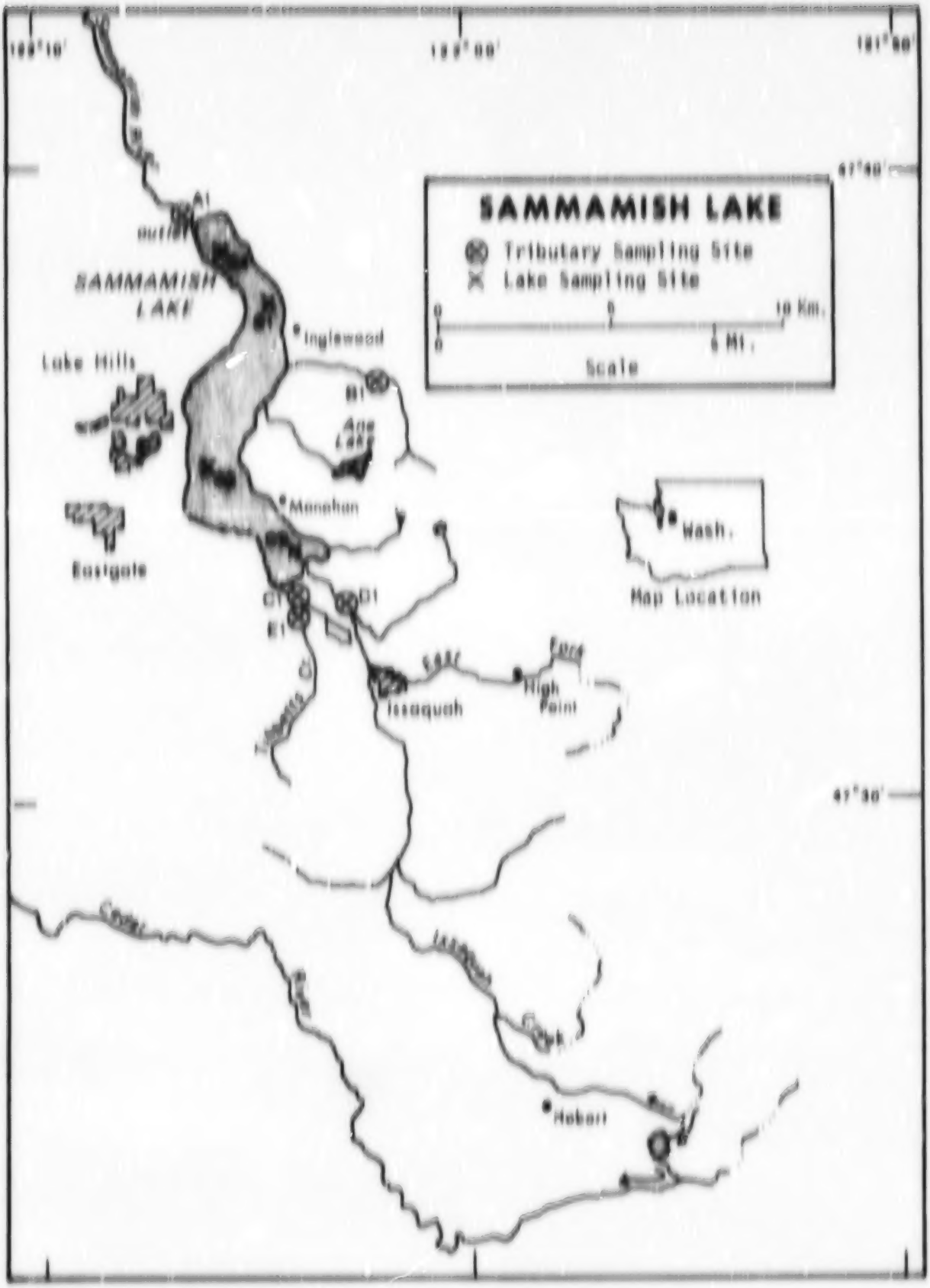
Major General Howard S. McGee, Adjutant General of Washington, and Project Officer Colonel Clinton C. Johnson, who directed the volunteer efforts of the Washington National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF WASHINGTON

LAKE NAME	COUNTY
American Lake	Pierce
Banks Lake	Grant, Douglas
Chelan Lake	Chelan
Diamond Lake	Pend Oreille
Green Lake	King
Keechelus Lake	Kittitas
Mayfield Lake	Lewis
Medical Lake	Spokane
Moses Lake	Grant
Ozette Lake	Clallam
Sammamish Lake	King
Lake Whatcom	Whatcom
Lower Granite Reservoir	Garfield, Whatcom


SAMMAMISH LAKE
Tributary Sampling Site
Lake Sampling Site
0
0
10 Km.
0
6 Mi.
Scale
122°10'
122°00'
121°50'
47°40'
47°30'
A1
outlet
SAMMAMISH LAKE
Inglewood
B1
Lake Hills
Ave
Monohan
Eastgate
Wash.
Map Location
C1
D1
E1
Issaquah
High Point
Tributaries
Snoq.
Fork
Raging
Creek
Rattlesnake
Lake
Snoq.
Tolt
Reservoir
Carnation
Duvall
Snoq.
Fall City
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Falls
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REPORT ON SAMMAMISH LAKE, WASHINGTON

STORET NO. 5311

I. CONCLUSIONS

A. Trophic Condition:*

Based upon survey data Sammamish Lake is considered mesotrophic with a tendency towards eutrophy during the spring. Chlorophyll a values ranged from 2.8 µg/l in October to 22.4 µg/l in March, with a mean of 7.3 µg/l. Secchi disc visibility was high throughout the sampling year. Potential for primary production as measured by algal assay control yield was high during spring and low during fall sampling. Of the 13 Washington lakes sampled in 1975, 6 had higher median total phosphorus levels (0.015 mg/l), 2 had higher median inorganic nitrogen values (0.210 mg/l) and 10 had higher median orthophosphorus levels (0.006 mg/l) than Sammamish Lake.

Survey limnologists did not report any problem algal blooms or macrophyte growths during the sampling year.

*See Appendix E.

B. Rate-Limiting Nutrient:

The algal assay results indicate phosphorus limitation in Sammamish Lake during spring and fall sampling dates (03/31/75; 10/28/75). The lake data substantiate primary limitation by phosphorus all three seasonal visits to the lake.

C. Nutrient Controllability:

1. Point sources -

There were no known municipal or industrial point sources contributing to the phosphorus load of Sammamish Lake during the 1975 sampling year. The town of Issaquah formerly discharged treated municipal and milk plant wastes to the lake; but as of 1968, the wastes were diverted to the Seattle-Renton plant which discharges outside the Sammamish Lake watershed. Ketelle and Uttormark (1971) report that this diversion accomplished an estimated 50% reduction in phosphorus entering the lake. Septic tanks were estimated to contribute 1.2% of the total phosphorus load to the lake in 1975.

The annual phosphorus loading of 0.31 g $P/m^2/yr$ is equal to Vollenweider's (1975) proposed "oligotrophic" level for a lake with such volume and retention time. Every effort should be made to control future phosphorus sources impacting the lake in order to maintain the existing water quality.

B. Nonpoint sources -

During the sampling year, Issaquah Creek contributed 75.6% of the total phosphorus load to Sammamish Lake, Tibbetts Creek contributed 9.4%, and ungaged drainage areas were estimated to have contributed 14.6% of the total.

The phosphorus export rate of Issaquah Creek was substantially greater during the sampling year than would be expected from nonpoint contributions alone (Section IV-D). This inflation is probably a result of either septic tank contributions or urban runoff from the city of Issaquah through which Issaquah Creek flows.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake morphometry data were provided by Emery, et al. (1973). Tributary flow data were provided by the Washington District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet. Precipitation values are estimated by methods as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 10.02 km^2.
2. Mean depth: 17.7 meters.
3. Maximum depth: 31.0 meters.
4. Volume: 350.814 x 10^6 m^3.
5. Mean hydraulic retention time: 637 days (1.8 years).

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area (km^2)	Mean flow (m^3/sec)
D-1 Issaquah Creek	141.7	4.14
E-1 Tibbetts Creek	13.0	0.25
Minor tributaries and immediate drainage -	81.5	2.02
Totals	236.2	6.41
2. Outlet - A-1 Sammamish River	253.0	6.37

C. Precipitation:

1. Year of sampling: 109.6 cm.
2. Mean annual: 90.6 cm.

III. LAKE WATER QUALITY SUMMARY

Sammamish Lake was sampled three times during the open-water season of 1975 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from four stations on the lake (Stations 03 and 04 were not sampled in March) and from a number of depths at each station (see map, page v). During each visit, depth-integrated samples were collected from each station for chlorophyll a analysis and phytoplankton identification and enumeration. During the first and last visits, 18.9-liter depth-integrated samples were composited for algal assays. Maximum depths sampled were 26.8 meters at Station 01, 24.4 meters at Station 02, 20.7 meters at Station 03, and 12.5 meters at Station 04. For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the maximum depth for each site. Results of the phytoplankton counts and chlorophyll a determinations are included in III-B. Results of the limiting nutrient study are presented in III-C.

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B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/31/75	1. Melosira	5,024
	2. Fragilaria	1,136
	3. Stephanodiscus	223
	4. Asterionella	661
	5. Synedra	344
	Other genera	344
	Total	8,122
07/17/75	1. Aphanocapsa	1,001
	2. Aphanothece	765
	3. Chroomonas	90
	4. Botryococcus	45
	5. Chlorophytan colony	45
	Other genera	135
	Total	2,161
10/20/75	1. Aphanocapsa	683
	2. Fragilaria	683
	3. Chroomonas	620
	4. Cryptomonas	186
	5. Aphanizomenon	31
	Other genera	63
	Total	2,174

8. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
03/31/76	01	22.4
	02	20.9
	03	****
	04	****
07/17/76	01	3.1
	02	4.6
	03	4.6
	04	4.7
10/28/76	01	4.5
	02	2.8
	03	3.1
	04	3.4

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. 03/31/76

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum Yield (mg/l-dry wt.)
Control	0.008	0.360	1.6
0.05 P	0.058	0.360	11.7
0.05 P + 1.0 N	0.058	1.360	26.7
1.00 N	0.008	1.360	0.8

b. 10/28/76

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum Yield (mg/l-dry wt.)
Control	0.006	0.130	0.5
0.05 P	0.056	0.130	5.6
0.05 P + 1.0 N	0.056	1.130	29.6
1.00 N	0.006	1.130	0.4

8. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential for primary productivity as measured by algal assay control yield was high in Sammamish Lake during spring sampling (03/31/75) and moderate during fall (10/28/75). The addition of phosphorus to the assay samples resulted in a significant increase in yield over that of the control, indicating phosphorus limitation in both seasonal samples. No growth response accompanied the addition of nitrogen alone.

The mean inorganic nitrogen to orthophosphorus ratios (N/P) in the lake data were approximately 45/1, 75/1, and 32/1 in the spring summer and fall, respectively, also indicating phosphorus limitation in Sammamish Lake.

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Washington National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff month of February when two samples were collected. Sampling was begun in September 1974, and was completed in August 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Washington District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual nutrient loads, in $kg/km^2/yr$, in Tibbetts Creek at Station E-1 and multiplying the means by the ZZ area in km^2.

A. Waste Sources :

1. Known municipal - None

2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source		kg P/yr	% of total
a.	Tributaries (nonpoint load) -		
	D-1 Issaquah Creek	4,635	75.5
	E-1 Tibbetts Creek	145	2.4
b.	Minor tributaries and immediate drainage (nonpoint load) -	895	14.6
c.	Known municipal STP's - None		
d.	Septic tanks* -	110	1.8
e.	Known industrial - None		
f.	Direct precipitation** -	345	5.6
	Totals	6,130	100.0
2.	Output - A-1 Sammamish River	4,450	
3.	Net annual P accumulation -	1,680	

*Estimate based on 381 lakeshore residences, 1 park and 1 camp.
**Estimated (See NES Working Paper No. 175).

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (nonpoint load) -		
D-1 Issaquah Creek	178,435	52.5
E-1 Tibbetts Creek	18,735	5.5
b. Minor tributaries and immediate drainage (nonpoint load) -	117,440	34.5
c. Known municipal STP's - None		
d. Septic tanks* -	4,165	1.2
e. Known industrial - None		
f. Direct precipitation** -	21,400	6.3
Totals	340,175	100.0
2. Output - A-1 Sammamish River	129,275	
3. Net annual N accumulation -	210,900	

*Estimate based on 381 lakeshore residences, 1 park and 1 camp.
**Estimated (See NES Working Paper No. 175).

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
Issaquah Creek	32	1,259
Tibbetts Creek	11	1,441

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P (mg/l)	Mean Total N (mg/l)
B-1 Unnamed Creek	0.025	1.668
C-1 Unnamed Canal	0.065	0.735

f. Yearly Loadings:

In the following table, the existing phosphorus annual loading is compared to the relationship proposed by Vollenweider (1975). Essentially, his "eutrophic" loading is that at which the receiving waters would become eutrophic or remain eutrophic; his "oligotrophic" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A "mesotrophic" loading would be considered one between "eutrophic" and "oligotrophic".

Note that Vollenweider's model may not apply to lakes with short hydraulic retention times or in which light penetration is severely restricted by high concentrations of suspended solids in the surface waters.

	Total Yearly Phosphorus Loading ($g/m^2/yr$)
Estimated loading for Sammamish Lake	0.31
Vollenweider's "eutrophic" loading	0.62
Vollenweider's "oligotrophic" loading	0.31

V. LITERATURE REVIEWED

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Vollenweider, R.A. 1975. Input-Output Models With Special Reference to the Phosphorus Loading Concept in Limnology. Schweiz. Z. Hydrol 37: 53-84.

VI. APPENDICES

APPENDIX A
CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107 x 10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX B
TRIBUTARY FLOW DATA

[illegible]

APPENDIX C
PHYSICAL AND CHEMICAL DATA

APPENDIX B

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

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APPENDIX E

PARAMETRIC RANKINGS OF LAKES SAMPLED BY NES IN 1975

STATE OF WASHINGTON

Mean or median values for six of the key parameters evaluated in establishing the trophic conditions of Washington lakes sampled are presented to allow direct comparison of the ranking, by parameter, of each lake relative to the others. Median total phosphorus, median inorganic nitrogen and median dissolved orthophosphorus levels are expressed in mg/l. Chlorophyll a values are expressed in µg/l. To maintain consistent rank order with the preceding parameters, the mean Secchi disc depth, in inches, is subtracted from 500. Similarly, minimum dissolved oxygen values are subtracted from 15 to create table entries.

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	[illegible] TOTAL P	[illegible] INORG N	SUB- [illegible] SEC	[illegible] CHLORO	[illegible] SEC DEPTH	[illegible] SUMM DEPTH P
5301	[illegible] LAKE	0.027	0.195	343.000	4.822	15.000	0.297
5302	[illegible] LAKE	0.021	0.040	344.520	7.373	10.000	0.307
5303	[illegible] LAKE	0.005	0.070	111.000	0.005	0.450	0.073
5304	[illegible] LAKE	0.014	0.040	103.467	14.537	14.250	0.010
5305	[illegible] LAKE	0.027	0.050	435.000	2.003	10.000	0.024
5306	[illegible] LAKE	0.007	0.040	290.250	1.400	0.250	0.040
5307	[illegible] LAKE	0.014	0.109	402.000	4.250	10.000	0.007
5308	[illegible] LAKE	0.075	0.225	491.724	11.425	15.000	0.144
5309	[illegible] LAKE	0.115	0.150	443.600	25.040	24.000	0.030
5310	[illegible] LAKE	0.010	0.110	403.333	1.225	7.250	0.095
5311	[illegible] LAKE	0.105	0.210	374.000	7.240	24.000	0.134
5312	[illegible] LAKE	0.006	0.320	290.000	3.427	10.000	0.090
5313	[illegible]	0.033	0.150	475.500	4.875	7.250	0.070

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